EFFECTS OF SOIL MEDIA AND FERTILIZATION
ON CONTAINER GROWN
HIBISCUS AND PANAX PLANTS

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ABSTRACT

Because of the relatively little work accomplished in Hawaii, and the pressing demands for information concerning media for nursery plant production, an experiment was designed to study some of these problems.

Hibiscus and panax plants were grown in nine soil and amended soil mixes. Combinations of two levels of soil, organic amendments (peat or wood shavings), and inorganic amendments (cinders or perlite), were used in making the mixes. Two fertilization levels were also used, and data were taken at 2.5 months and 5.0 months. A randomized block design was used.

Grade and growth of plants were determined at both dates. At 5.0 months infiltration rates, water-holding capacity, available water, and bulk density data were also taken. Statistical analysis of these properties was carried out for the high fertility portion of the experiment. Statistical analyses were also carried out on the differences in grade and growth of both species at both observation dates due to different fertility levels.

Few significant differences in grade or growth of these two species were detected at 2.5 months. At 5.0 months several significant differences were apparent in grade and growth. No consistent effect of soil treatment on grade and growth of these two species at the two observation dates

was apparent. When grade or growth was affected by soil treatments, the lower percentage of soil was always better than the higher percentage of soil, and amended soil was always better than soil alone.

There were several significant differences in the physical properties of the different soil media. Infiltration rate and available water were higher in amended soil than in soil alone. Bulk density and water-holding capacity were lower in amended soil than in soil alone.

There were several significant differences in these properties due to percentage of soil, inorganic amendments, and organic amendments as well as several significant interactions between components of the media. Water-holding capacity was highest in mixes with the higher percentage of soil. Peat mixes had significantly higher bulk densities than did wood shaving mixes.

Grade and growth of plants grown at the high level of fertility were almost always greater than grade and growth of plants grown at the low fertility level.

Many differences were found especially in the physical properties of the mixes. Though the physical properties differed no treatment seemed to suffer on this account. The differences in growth and grade were relatively minor, and would probably be less important as a determining factor than the cost of the media.

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INTRODUCTION

A major portion of nursery plants in Hawaii are produced in containers. Though this production may not be on the vast scale of some mainland operations it is still of considerable economic importance. Over the last several years much attention has been directed to various problems peculiar to container growing in several geographic and climactic areas of the mainland. Special attention has been focused on the problems involved in formulating soil mixes for container production in these areas.

Problems of container growing which relate to the growing media are first physical characteristics. Soils of almost all types tend to become compacted when used for container growing. This compaction is often accompanied by a reduction in water-holding capacity, drainage, aeration, water infiltration rate, and perhaps root penetration. Soil amendments can often prevent these undesirable changes in the soil fully or at least to the extent that plants of acceptable quality may be grown economically. Next commercial nurserymen desire to standardize their growing programs and therefore require a growing media which can be reproduced from year to year. With the scarcity of good soils available for this purpose in the areas where growers are located, obtaining an extensive supply of good quality soil becomes a problem. Locally available amendments may not be of standard quality. On the other hand several amendments of standard quality are almost universally available. Available low quality soils are for this purpose quite uniform in any given area and often a small amount of research will reveal locally available amendments which will satisfy this condition. When used properly, these amendments in conjunction with available soils form soil media with desirable qualities.

Many soil mixes which have been prepared to date are much lighter than soil but still are capable of supporting the plant material satisfactorily. These light weight media have the advantages of reducing labor and transportation costs. In areas not protected from high winds light media may be a disadvantage. In certain instances amendments may help hold soil material against the washing action of certain irrigation practices. Other less important considerations would be cation exchange capacity, sterility and nutrient levels. These factors can be compensated for by various growing practices.

Though many problems may be overcome at least in part by using artificial media a major factor affecting their use is cost. Widely available uniform amendments such as peat and perlite are generally expensive especially in areas where they must be imported. Soil of course is usually the cheapest component of the mix. Locally available amendments must be examined for suitability and with concern for cost. Also the ease with which these materials are worked must be considered. Any material which requires more or special handling by the nurseryman during such standard operations as moving, storing, mixing, sterilizing, or potting will not be as acceptable as one that does not. The admendment should be sterile and not deteriorate appreciably during the proposed growing period. It may be advantageous to consider growing practices, plant material, and the growing area, especially climate, when selecting a particular medium.

Although these aspects have received considerable attention in various areas of the mainland and articles appear regularly in trade publications, little work has been done in Hawaii where there are perhaps greater differences between growing conditions, soils, and amendment availability than between other areas of the United States. Several factors make container growing attractive to Hawaiian nurserymen. Since more plants can be grown per unit area by this method high land values encountered in Hawaii may be minimized. Also plant sales to home owners are well developed and container grown plants are not only a convenience, but an attractive package for this type sale. Finally the lack of pronounced dormant seasons would restrict somewhat the transplanting of many nursery crops and limit others to seasons of relative dormancy if container grown stock, which suffers less shock on transplanting, was not used.

Because of the importance of these related problems and the relatively little work accomplished to date this experiment was initiated to study these problems in Hawaii.

REVIEW OF LITERATURE

Plants have been grown in containers since early recorded history. Even then artificial soil media were used. In the nineteen thirties, Pinney (20) noted a new horticultural industry, the growing of plants in containers. Its beginnings were most prominent in California though it quickly spread to all corners of the country as used metal cans became available, especially the number 10 or gallon size.

Container production is still growing today and has in many areas surpassed the conventional method of plant production. Although much container growing is carried on in used gallon cans many containers have been especially designed for this purpose. A few of these were briefly described by Dickey (5) and Jones and Haskins (14). Descriptions of many more may be found in nontechnical articles of trade publications.

Advantages derived from container growing are many. Conover and Joiner (3) mentioned an increase in the success of transplanting. Joiner and Conover (12, 13) stated that container growing more efficiently utilizes labor and production and sales areas, extends planting seasons, and increases the transportability of the product while allowing better control of environment and cultural practices. They also recognized that container growing presents special problems in watering, fertilization, soil temperature variation and handling.

These special problems are to some extent all related to the soil medium. Much has been written concerning the relationships of different medium components, their combination, and their relative percentage in the medium to these special problems. Since the development of a soil mix is primarily a local problem, work has been done in many geographic areas. An example of this is the U. C. mix which was mentioned by Richards et. al. (21). In Hawaii work with artificial media was first reported in 1953 by Kamemoto and Nakasone (15). They worked with anthuriums, a speciality crop of considerable importance in Hawaii. Later in 1968 Voss and Watson (28) developed the U. H. potting mix. This mix contains no soil, a special advantage if rooted plants must pass quarantine inspections prior to exportation.

Some materials which have been examined as possible soil substitutes or soil amendments were peat, sand, muck, wood shavings, sawdust, perlite (5), and pine bark (11). Self (23) tried Bet R Grow, a sugar cane by-product. Conover and Joiner (4) worked with garbage compost. In Hawaii Kamemoto and Nakasone (15) grew anthuriums in taro peel, tree fern fiber, coffee parchment, macadamia nut hulls, leaf mold, and black sand. Voss and Watson (28) investigated mill ash, "Volcanite" trachyte pumice, and red cinders.

A few of the mixes reported were 2/3 pine bark 1/3 perlite, 1/2 sand 1/2 peat, 1/2 sand 1/2 pine bark, 2/3 sawdust 1/3 peat by Conover and Joiner (3). Dickey and Poole (7) used a mix of 1/3 peat, 1/3 perlite, and 1/3 sandy soil. White and Mastalerz (30) varied soil, peat and perlite from 0 to 10 parts in mixes of ten parts. In Hawaii Kamemoto and Nakasone (15) reported on mixes of 1/2 tree fern fiber 1/2 black sand, 1/2 soil 1/2 wood shavings, 1/2 soil 1/2 tree fern fiber, 3/4 tree fern 1/4 manure, and 3/4 wood shavings 1/4 manure. Voss and Watson (28) combined Volcanite and tree fern fiber, cinders and tree fern fiber, and Volcanite and mill ash at levels of 1/3 to 2/3, 2/3 to 1/3, and 1/2 to 1/2.

Certain physical properties of soils are of utmost importance to the growing plant. Foremost among these are aeration, compaction, water-holding capacity, and infiltration rate of water. While a soil in the field may have these properties balanced so that acceptable plant growth may be made, growers of container stock have found few soils which retain these properties in a favorable balance in the container.

Little work directly concerned with compaction in containers was found in the literature, though it is often mentioned with respect to other physical properties and root growth of plants.

Proper aeration of the soil allows a sufficient supply of oxygen to reach the plant roots. In the field a soil with approximately 25% by volume air space is preferred, or one with 50% of the pore space taken up by air (17, 22). Self (24) states that 20-30% air by volume is satisfactory for growing woody ornamentals in containers. Maintaining a proper percent by volume of air space in containers was recognized as a problem by Carlson and Sink (2).

Water-holding capacity has received comparatively more work than other physical properties. Millar, Turk and Foth (17) and Russell (22) regard 25% by volume or 50% of the pore space filled with water as approaching the optimum for plant growth, although in field work water-holding capacity is seldom reported by volume. Working with media of different bulk densities and separate soil systems of specific volumes requires that water-holding capacity in container work be expressed on a volume basis (12, 29). Fulmer (11) found the water-holding capacity of coarse pine bark too low and that the addition of peat increased water-holding capacity to an acceptable level. Joiner and Conover (13) found little difference in water-holding capacity for different ratios of sand and peat, and sand and bark. Self (24) noted that several common amendments, notably peat have excessively high water-holding capacities. Richards et al. (21) found that water-holding capacity of soil always increased with the addition of peat or wood shavings and decreased with the addition of sand. White and Mastalerz (30) reported higher amounts of moisture are held by soils in containers than are held by similar soils in the field. Others who recognized the importance of a reasonable water-holding capacity were Carlson and Sink (2) and Self (24). Generally irrigation practices can be regulated enough to produce acceptable plants in containers over a fairly wide range of water-holding capacities.

In the field drainage, or the percolation of water downward thus preventing water-logging, is the most important aspect of water infiltration. In containers how quickly water is absorbed by the soil is also important. Conover and Joiner (3) noticed an increase in infiltration rate due to the addition of wood products to soil mixes. Richards et al. (21) found that sand, peat and wood shavings increased infiltration rates of soil mixes, with the highest percentages of these materials giving the highest infiltration rates. White and Mastalerz (30) noted the importance of maintaining a reasonable infiltration rate. Richards et al. (21) determined that an infiltration rate of 2 cm per hour was sufficient to produce acceptable plants. Some soils alone do not have as rapid infiltration rates. They also found a positive correlation between infiltration rates of samples of mixes compacted mechanically and samples in which plants had been grown. The bulk densities of mechanically compacted samples and samples in which plants had been grown were also positively correlated.

Bulk density is the weight per unit volume of a soil.

Self (24) mentioned this property in connection with plant growth, and here the better growth was more likely due to other factors rather than low bulk density. In container production bulk density becomes quite important. Joiner and Conover (12), Richards et al. (21), and Self (24) all reported the advantage in transporting plants grown in media of low bulk densities. Lightweight media save labor in handling and in freight costs. Joiner and Conover (12) stated that most organic amendments have low bulk densities. Richards et al. (21) reinforced this statement by reporting lower bulk densities in media when peat or wood shavings were added. They also observed increases in bulk density with the addition of sand. Materials with very low bulk densities may not support plants properly. Joiner and Conover (12) caution against using too high a percentage of low bulk density organic amendments causing a decrease in cation exchange capacity in milliequivalents, me, per unit volume while causing an increase in me per 100 grams.

Cation exchange capacity is one of the most important chemical properties of the soil. It is the ability of the soil to hold certain plant nutrients. Conover and Joiner (3) state that unless the media has a sufficiently high cation exchange capacity, excessive leaching of nutrients may take place. Thus more frequent or heavier applications of fertilizer will be required for proper plant growth. Joiner and Conover (12) believe that when working with containers the most useful expression of cation exchange capacity is me per unit volume. They (13) found the highest cation exchange capacities in 1:1 mixes of sand with either bark or peat.

pH, a measure of soil acidity, is another important chemical property of the soil. Various crops have different pH requirements. Adjustment of pH during the preparation of the media, usually by adding calcium carbonate, was suggested by several workers. Kamemoto and Nakasone (15) noted a general rise in media pH over a period of time. Knowledge of specific media concerning pH and change in pH is necessary to make the appropriate adjustments.

The soluble salt content of the media may in some instances be important. Conover and Joiner (4) found that garbage compost when used as a soil amendment supplied certain amounts of various nutrients. Most workers have used materials low in nutrients and have concluded that it is usually more economical to use these materials and to supply all nutrients by fertilization. Flint and McGuire (10) cautioned against a build up of soluble salts due to fertilization and irrigation practices. Leaching was recommended to lower the level of soluble salts in soil mixes both initially and during the growing period. White (29) noted restriction of growth at high levels of soluble salts.

Other properties of soil mixes and amendments that require consideration are cost, availability over an extended period of time at a standard quality and sterility. Sterility is important in reducing weeds and disease, eliminating the necessity of sterilization. Some amendments tend to decompose rapidly possibly necessitating replacement as was noted by Kamemoto and Nakasone (15). Kamemoto and Nakasone (15) and Vihjoen and Fred (27) speculated that toxic substances might be produced during the breakdown of certain materials.

Growing practices are important in the production of container stock. These practices of necessity differ from those used in field production, and considerable difference may be necessary even between different media or different growing areas due to slightly different micro climates.

Irrigation of container stock was investigated by Patterson (19) who noted a relationship between the incidence of certain fungal problems and irrigation practices. Joiner and Conover (12) and White (29) expressed the feeling that the desirability of a medium was dependent on proper irrigation. White (29) could not find a method of more than limited use in determining irrigation frequencies. Electronic, tensiometric, and meteorological instruments were used. He also divided the problem of irrigation into four parts: (1) when is it necessary to irrigate? (2) how much water should be applied? (3) what is the best method of application? and (4) what effect does control of these factors have on quality and quantity of plant growth?

Carlson and Sink (2) were of the opinion that similar quality plants could be grown in any mix they used if water and fertilization were in proper supply.

Fertilization is dependent to a large extent on the cation exchange capacity of the soil mix. A high cation exchange capacity reduces the leaching rate of nutrients caused by daily watering. Most media are low in nutrients practically all of which must be added as fertilizer according to Self et al. (25). White (29) and Flint and McGuire (10) suggest irrigation and fertilization be carried out using the same system. Fertilization may be accomplished during every watering cycle or some other convenient schedule. Kelly (16) noted the necessity of frequent fertilizer applications to container grown stock, and speculated that slow release fertilizers could cut down on the number of applications. He found eight pounds per cubic yard potassium frit incorporated in the soil mix was sufficient for the production of several woody ornamental species. Carlson and Sink (2) found significant differences in plant tissue of nitrogen, calcium, and boron. They found significant differences in phosphorus, potassium, and calcium in the soil, but did not observe empirical differences in growth or quality of plants. Flint (9) determined 10 to 20 ppm nitrogen in soil extracts by the Spurway method were associated with maximum growth of forsythia, viburnum, taxus, pieris, and rhododendron. Flint (8) got significant differences in growth up to 0.9 ppm phosphorus in soil extracts, but not above, indicating that that level is approximately sufficient for growth of forsythia, weigela, taxus and pieris. Flint and McGuire (10) established soil extract levels for nitrogen of 10-30 ppm and potassium 10-30 ppm as being optimum for continuous fertilization regimes using forsythia and viburnum. Dickey and Poole (7) reported an interaction between nitrogen and potassium on rhododendron. When potassium was low increasing nitrogen caused poorer visual grades.

When large amounts of readily decomposed organic matter are incorporated into the soil the microorganisms which decompose this matter may utilize large amounts of nitrogen. This effect was reported by Vihjoen and Fred (27) in 1924. Legumes and plants well supplied with nitrogen performed best in soils containing decomposable organic matter. Conover and Joiner (3) also mentioned this effect and its importance to those using media containing decomposable organic matter.

Many amendments and poor quality soils may not have sufficient quantities of certain minor elements for good plant growth. Dickey (5) speculated that deficiency symptoms may develop and reported a deficiency of copper in several species.

Jones and Haskins (14) found poor root habit in porous clay pots. Non-porous clay pots and cement pots apparently did not cause this adverse effect. Remarks are often found concerning the possible lasting effects of containers on root systems. One report by Dickey (6) however found no harmful effects carried into the field by plants grown in containers for twenty months.

MATERIALS AND METHODS

Cuttings from the Common Pink Hedge Hibiscus, Hibiscus cameroni, were taken on May 28, 1967, and cuttings from the Guilfoyle Panax, Polyscios guilfoylei, were taken on June 28, 1967. Nine soil and soil amendment mixes were prepared as shown in Table I. During preparation, calcium carbonate equivalent to 5 pounds of high grade limestone per cu. yd. was incorporated in each mix. Rooted cuttings of both species were potted on the 21st of August. Eight plants of each species were placed in individual 6" Lerio cans of each mix, and placed under the greenhouse bench for one week. On August 27th all plants were moved to 43% shade under saran cloth. As space became available on October 10th all plants were transferred to 27% shade under saran cloth. Fertilization was accomplished at monthly intervals: September 30, 1967, October 28, 1967, December 4, 1967, December 31, 1967, and January 29, 1968. Two levels of fertilizer were applied: N 400, P 176, and K 332, and N 800, P 352, and K 664, on the basis of elemental pounds per acre per year. Four cans of each plant species in each mix received each fertilization level. This permitted each separate treatment to be replicated four times. A randomized block design was used.

After 2.5 months, growth measurements were taken and plants were graded (Figures 1 and 2). At the termination of the experiment, March 7, 1968, the plants were again graded and measured as before. Height was measured from the top of

TABLE I. COMPOSITION OF THE VARIOUS SOIL MIXES

Soil Mix No.	Parts	Material
1	1	Soil
2	1 1 1	Soil Cinders Peat
3	3 1 1	Soil Cinders Peat
4	1 1 1	Soil Perlite Peat
5	3 1 1	Soil Perlite Peat
6	1 1 1	Soil Cinders Wood Shavings
7	3 1 1	Soil Cinders Wood Shavings
8	1 1 1	Soil Perlite Wood Shavings
9	3 1 1	Soil Perlite Wood Shavings

Figure 1. Hibiscus plants grades 1-4 from left to right.

Figure 2. Panax plants grades 1-4 from left to right.

the can to the uppermost growing point. Width was measured at the widest point. Grades were established from 1 to 4, four being best and 1 being poorest quality. At the conclusion of the experiment other data were also taken. Water was allowed to infiltrate into each can of water saturated media under a 2" head. When this flow was constant the quantity of water passing through the system was collected over a five minute interval. The supersaturated soil was allowed to drain for 20 minutes, which was sufficient time for all soil media to cease active drainage. Then the plant, can and saturated soil mix were weighed. All plants were then deprived of water until reaching the approximate permanent wilting point. Plants that recovered their turgor overnight were not considered wilted. They were then reweighed giving the available moisture by direct subtraction. Then the plant was removed, and soil and can were reweighed. Soil samples were taken from each can and moisture was determined so that water held at the wilting point could be calculated and added to available moisture as an estimate of water-holding capacity. By dividing the moisture values by average soil volume these values were converted to percent by volume. From the average soil volume and the dry weight of the soil media bulk density was calculated.

Analysis of variance was performed for grade and (H+W)/2, also referred to as growth, of both species at the high fertility level at both 2.5 and 5.0 months. Analysis of variance was performed for infiltration rates, total water, available water, and bulk density at 5.0 months for both species' growing media at the high fertility level. Analysis of variance was also performed for grade and growth combining both fertility levels at both dates of observation and for both species. Analysis of variance tables may be found in the Appendix.

The soil used in this experiment was of the Kaneohe family. A typical soil available locally in the trade. It was mostly subsoil material and low in nutrients. The peat moss and perlite were fairly expensive, uniform, imported amendments common in the trade. Wood shavings are a by-product available locally and in most other areas, reasonably priced and fairly uniform in quality. All the above amendments have low bulk densities. The other amendment, Molokai cinders is locally available at reasonable cost and uniform quality. It has a much higher bulk density than the other amendments.

RESULTS AND DISCUSSION

There were several significant differences in plant growth expressed as (H+W)/2 and grade, of plants grown in the several soil mixes at the high fertility level.

At 2.5 months differences in grade and growth were detected only in panax plants. Visual grades of panax plants (Table II) were higher in mixes containing cinders with the lower percentage of soil. Soil percentage had no effect on grade in mixes containing perlite. Growth of panax at 2.5 months was greater in mixes containing the lower percentage of soil (Table III).

At 5.0 months the visual grade of hibiscus was demonstratively higher in amended soils than in soil alone (Table IV). Visual grades of panax plants at 5.0 months (Table V) were higher in soil mixes with the lower percentage of soil. The visual grade of panax plants at 5.0 months was also higher (Table VI) in mixes containing perlite rather than cinders.

There is little difference in growth of hibiscus at 5.0 months (Table VII) between mixes with peat or wood shavings at the lower percentage of soil, but at the higher percentage of soil, mixes with peat produced larger plants than mixes with wood shavings. Little difference in growth of hibiscus at 5.0 months (Table VIII) was shown between plants produced in peat or wood shavings when perlite was also an amendment, but when cinders were used, larger plants were produced in

TABLE II. INTERACTION OF PERCENTAGE SOIL AND INORGANIC AMENDMENTS ON VISUAL GRADE OF PANAX AT 2.5 MONTHS

	Percentage Soil	
Inorganic Amendment	33.3%	60.0%
Cinders	3.87	2.75
Perlite	3.37	3.37

Linear percentage soil X linear inorganic amendment, 5% level

TABLE III. EFFECT OF SOIL PERCENTAGE ON (H+W)/2(cm) OF PANAX AT 2.5 MONTHS

Percentage Soil	Average Growth
33.3%	29.62
60.0%	25.84

Significant at the 5% level

TABLE IV. EFFECT OF SOIL AND AMENDED SOIL MEDIA ON GRADE OF HIBISCUS AT 5.0 MONTHS

Growing Medium	Average Grade
Soil	2.50
Amended Soil	3.31

Significant at the 1% level

TABLE V. EFFECT OF PERCENTAGE SOIL ON VISUAL GRADE OF PANAX AT 5.0 MONTHS

Percentage Soil	Grade
33.3%	3.12
60.0%	2.62

Significant at the 1% level

TABLE VI. EFFECT OF INORGANIC AMENDMENTS ON VISUAL GRADE OF PANAX AT 5.0 MONTHS

Inorganic Amendment	Grade
Perlite	3.12
Cinders	2.62

Significant at the 1% level

TABLE VII. INTERACTION OF SOIL PERCENTAGE AND ORGANIC AMENDMENTS ON (H+W)/2(cm) OF HIBISCUS AT 5.0 MONTHS

	Percentage Soil	
Organic Amendment	33.3%	60.0%
Peat	78.12	84.68
Wood Shavings	80.56	74.12

Linear percentage soil X linear organic amendment, 5% level

TABLE VIII. INTERACTION OF ORGANIC AMENDMENTS AND INORGANIC AMENDMENTS ON (H+W)/2 (cm) OF HIBISCUS AT 5.0 MONTHS

	Inorganic Amendment	
Organic Amendment	Cinders	Perlite
Peat	85.31	77.50
Wood Shavings	75.06	79.50

Linear inorganic amendment X linear organic amendment, 5% level mixes containing peat than in those containing wood shavings.

Table IX shows the interaction of percentage soil and inorganic amendments on growth of panax at 5.0 months. In mixes containing perlite, little effect on growth of panax plants was noted due to the different percentages of soil in the mix, but in mixes containing cinders, larger growth measurements were recorded for plants grown in mixes with the lower soil percentage.

From the analysis of the grade and (H+W)/2(cm) data, it is apparent that no soil mix or soil mixes were either consistently better or worse than any other. It is also apparent that none of the differences between the mixes has had any consistent effect on grade or growth of these two species. To some extent this lack of consistent findings might be attributed to the natural differences in the two plant species, and the differences in sensitivity of the two species at different ages. Most probably however this lack of consistency reflects no really outstanding differences between the various mixes as to their effect on grade and growth of these two species.

Several affects of soil mix composition which were noted are possibly worthy of reiteration, since they may be useful to nurserymen. However, from the strict limitations of the experiment it is impossible to draw specific conclusions. Grade at 2.5 months of panax and growth at 5.0 months of panax was better in cinder mixes containing the lower soil

TABLE IX. INTERACTION OF PERCENTAGE SOIL AND INORGANIC AMENDMENTS ON (H+W)/2 (cm) OF PANAX AT 5.0 MONTHS

	Percentage Soil	
Inorganic Amendment	33.3%	60.0%
Cinders	51.56	39.50
Perlite	47.00	44.93

Linear percentage soil X linear inorganic amendment, 5% level

percentage. It is also interesting to note that whenever soil percentage had a significant effect on grade or growth, the lower soil percentage was the better treatment. Also the visual grade of hibiscus at 5.0 months was better in amended soils than in soil alone.

The physical properties of the soil mixes investigated were: (1) infiltration rate, (2) water-holding capacity, (3) available water, and (4) bulk density. These properties varied considerably between the various mixes. The differences in these properties between the amended soils and soil alone are given in Table X. Higher infiltration rates were observed in the amended soil than in soil alone, but was statistically significant for hibiscus only. In both plant species amended soil had lower water-holding capacity than did soil alone, although amended soils did have significantly more available water than did soil alone. Amended soils had lower bulk densities than did soil alone in hibiscus and panax.

The interaction of the organic and the inorganic amendments on infiltration rates (Table XI) was of the complete reversal type. The combinations of perlite and wood shavings and of peat and cinders had the highest infiltration rates.

In mixes in which hibiscus plants were grown (Table XII) there was little difference in the water-holding capacity of the two inorganic amendments with peat, however with wood

TABLE X. EFFECT OF SOIL AND AMENDED SOIL MEDIA ON INFILTRATION RATE, BULK DENSITY, WATER-HOLDING CAPACITY, AND AVAILABLE WATER

		Soil Medium	
Physical Property	Plant Material	Soil Alone	Amended Soil
Infiltration Rate (ml/5min.)	Hibiscus	161.00	1089.34*
	Panax	288.50	532.93 N.S.
Water-Holding Capacity (ml/cc)	Hibiscus	.579	.510**
	Panax	.601	.543**
Available Water (ml/cc)	Hibiscus	.264	.319**
	Panax	.353	.397**
Bulk Density (gm/cc)	Hibiscus	.538	.428**
	Panax	.623	.463**

N.S. Non-significant
*Significant at the 5% level
**Significant at the 1% level

TABLE XI. INTERACTION OF INORGANIC AMENDMENTS AND ORGANIC AMENDMENTS ON INFILTRATION RATES OF CONTAINERS (ml/5 min) OF MEDIA IN WHICH PANAX PLANTS WERE GROWN

	Inorganic Amendment	
Organic Amendment	Cinders	Perlite
Peat	596.12	405.87
Wood Shavings	381.87	747.87

Linear inorganic amendment X linear organic amendment, 5% level

TABLE XII. INTERACTION OF ORGANIC AMENDMENTS AND INORGANIC AMENDMENTS ON WATER-HOLDING CAPACITY (ml/cc) IN MEDIA WHICH HIBISCUS PLANTS WERE GROWN

	Inorganic Amendment	
Organic Amendment	Cinders	Perlite
Peat	.542	.533
Wood Shavings	.463	.503

Linear inorganic amendment X linear organic amendment, 5% level shavings water-holding capacity was greater in mixes containing perlite rather than cinders. In the mixes used to grow hibiscus (Table XIII) greater water-holding capacity was found in those with the higher percentage of soil. Water-holding capacity was also greatest (Table XIV) in mixes with the higher percentage of soil in which panax plants had been grown. Water-holding capacity was also greater for mixes amended with perlite rather than cinders when panax plants were grown (Table XV).

Of the media combinations used for growing hibiscus plants the combination of peat, perlite and low soil percentage had the highest amount of available moisture (Table XVI). Peat and perlite, peat and cinders, and wood shavings and perlite at the higher soil percentage and wood shavings and perlite and peat and cinders at the lower soil percentage were all nearly equal. Cinder and wood shaving mixes at both soil percentages were nearly equal and somewhat lower in available water than these other treatments. In soil mixes in which panax plants were grown (Table XVII) available moisture was greater in mixes containing perlite rather than cinders.

The bulk densities of media in which hibiscus plants were grown (Table XVIII) containing cinders was almost the same at both soil percentages, but large differences in bulk density were apparent between the soil percentages in mixes amended with perlite. In mixes in which hibiscus plants

TABLE XIII. EFFECT OF PERCENTAGE SOIL ON WATER-HOLDING CAPACITY (ml/cc) IN MEDIA IN WHICH HIBISCUS PLANTS WERE GROWN

Percent Soil	Total Moisture
33.3%	.474
60.0%	.547

Significant at the 1% level

TABLE XIV. EFFECT OF PERCENTAGE SOIL ON WATER-HOLDING CAPACITY (ml/cc) IN MEDIA IN WHICH PANAX PLANTS WERE GROWN

Percent Soil	Total Moisture
33.3%	.526
60.0%	.560

Significant at the 5% level

TABLE XV. EFFECT OF INORGANIC AMENDMENTS ON WATER-HOLDING CAPACITY (ml/cc) IN MEDIA IN WHICH PANAX PLANTS WERE GROWN

Inorganic Amendment	Total Moisture
Cinders	.521
Perlite	.567

Significant at the 5% level

TABLE XVI. INTERACTION OF PERCENTAGE SOIL, INORGANIC AMENDMENTS, AND ORGANIC AMENDMENTS ON AVAILABLE WATER (ml/cc) IN MEDIA IN WHICH HIBISCUS PLANTS WERE GROWN

Percent Soil	Organic Amendment	Inorganic Amendment	Available H_2O
33.3%	Peat	Cinders	.310
"	"	Perlite	.398
"	Wood Shavings	Cinders	.273
"	" "	Perlite	.331
60.0%	Peat	Cinders	.325
"	"	Perlite	.327
"	Wood Shavings	Cinders	.265
"	" "	Perlite	.321

Linear percentage soil X linear inorganic amendment X linear organic amendment, 5% level

TABLE XVII. EFFECT OF INORGANIC AMENDMENTS ON AVAILABLE MOISTURE (ml/cc) IN MEDIA IN WHICH PANAX PLANTS WERE GROWN

Inorganic Amendment	Available Moisture
Cinders	.374
Perlite	.419

Significant at the 1% level

TABLE XVIII. INTERACTION OF PERCENTAGE SOIL AND INORGANIC AMENDMENTS ON BULK DENSITY (gm/cc) OF MEDIA IN WHICH HIBISCUS PLANTS WERE GROWN

	Percent Soil	
In organic Amendment	33.3%	60.0%
Cinders	.501	.538
Perlite	.259	.415

Linear percentage soil X linear inorganic amendment, 1% level

were grown (Table XIX) containing perlite the organic amendments caused little difference in bulk density, wood shavings being slightly higher than peat. On the other hand the bulk densities of the cinder mixes were affected more by the organic amendment, peat mixes having considerably higher bulk densities than wood shaving mixes. Although the bulk density of the cinder mixes in which panax plants had been grown (Table XX) with the higher soil percentage is higher, this difference is shown to a greater degree in the perlite mixes. The bulk densities of the mixes containing peat in which panax plants had been grown (Table XXI) were significantly higher than the bulk densities of the mixes containing wood shavings.

Infiltration rate is important with respect to irrigation efficiency, proper aeration of the plant roots, and the leaching of nutrients from the soil mix. Because of the interrelationship of these factors infiltration rates of either extreme are to be avoided. White and Mastalerz (30) determined infiltration rates for mixes of soil, peat, or perlite. Each component was varied from 0 to 10 parts of the mix. The total parts in each mix was 10. Their findings would tend to confirm the above results that amended soils have higher infiltration rates than soil alone. Also higher levels of amendments seemed to increase infiltration rate, and perlite increased infiltration rates more than peat at the same level. The interaction of organic and inorganic

TABLE XIX. INTERACTION OF ORGANIC AMENDMENTS AND INORGANIC AMENDMENTS ON BULK DENSITY (gm/cc) OF MEDIA IN WHICH HIBISCUS PLANTS WERE GROWN

	Organic Amendment	
Inorganic Amendment	Peat	Wood Shavings
Cinders	.556	.482
Perlite	.323	.351

Linear inorganic amendment X linear organic amendment, 1% level

TABLE XX. INTERACTION OF PERCENTAGE SOIL AND INORGANIC AMENDMENTS ON BULK DENSITY (gm/cc) OF MEDIA IN WHICH PANAX PLANTS WERE GROWN

	Percentage Soil	
Inorganic Amendment	33.3%	60.0%
Cinders	.508	.574
Perlite	.328	.440

Linear percentage soil X linear inorganic amendment, 5% level

TABLE XXI. EFFECT OF ORGANIC AMENDMENTS ON BULK DENSITY (gm/cc) OF MEDIA IN WHICH PANAX PLANTS WERE GROWN

Organic Amendment	Bulk Density
Peat	.478
Wood Shavings	.447

Significant at the 1% level

amendments reported above could be of some importance since it seems that the effects of amendments on infiltration rate may be amplified or diminished when they are in certain combination.

Water-holding capacity in itself probably is of little importance, but the fraction of it which is available to the plant is important. If it is too high there will be insufficient oxygen for the roots of the plants. As was reported above soils alone had significantly more water-holding capacity than amended soils, and mixes with the higher percentage of soil had a higher water-holding capacity than mixes with the lower percentage of soil. This is in contrast to the findings of Self (24) who states that amendments may hold more water than soil. No doubt different soils have different water-holding capacities.

Available water is probably more important to the plant than water-holding capacity, especially if conditions of water stress are encountered. Probably because proper irrigation practices were followed throughout the growing period there were no obvious indications that the differences detected in available water in the different mixes influenced grade or growth of the plants. Many mixes with the highest water-holding capacity actually had less available water (Figures 3 and 4). Amended soils had more available water than soil alone. Of the media in which hibiscus was grown the highest amount of available water was found in the mix

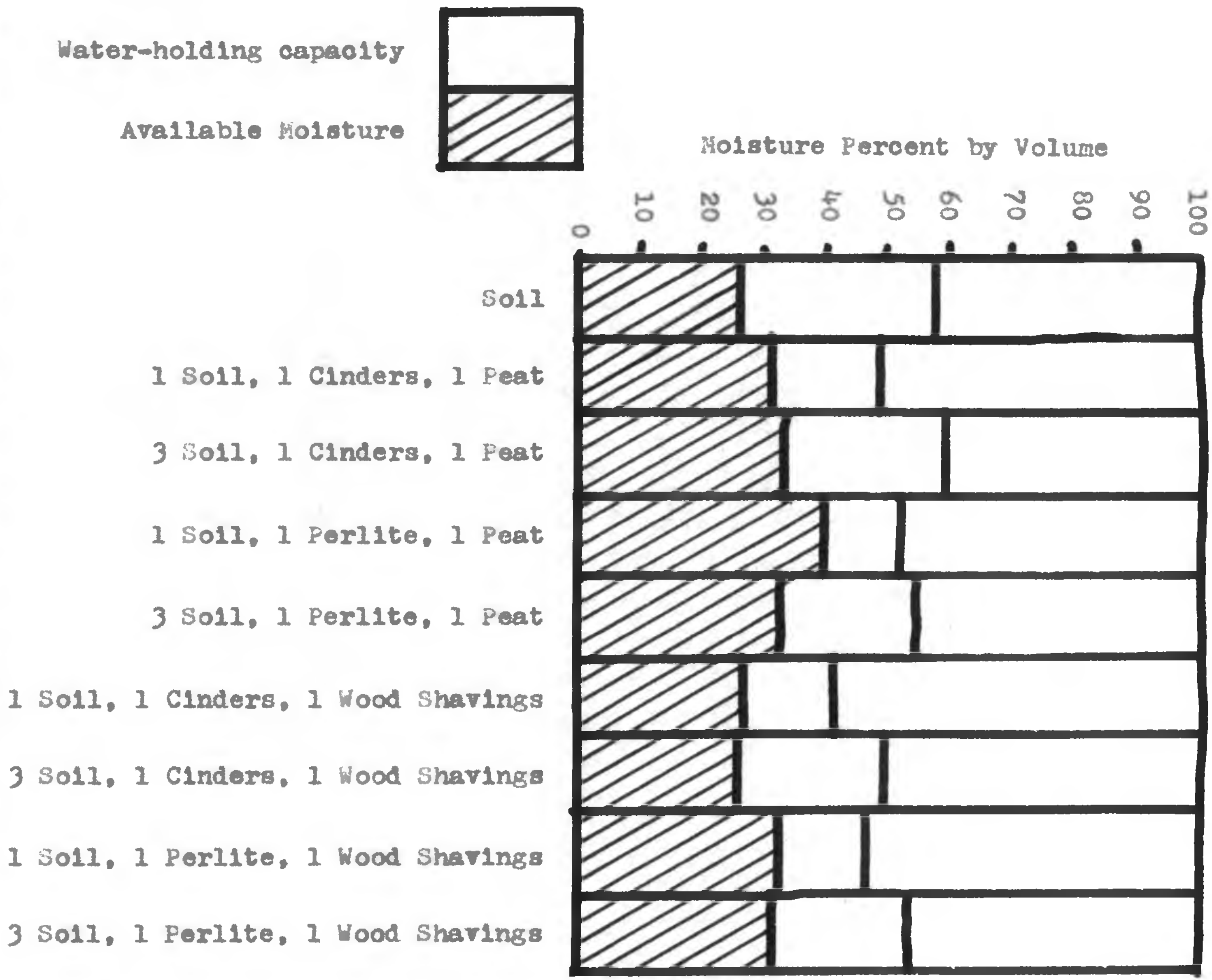

Figure 3. Water-holding capacity and available moisture in percent by volume of saturated soil in which hibiscus plants were grown at the high fertility level

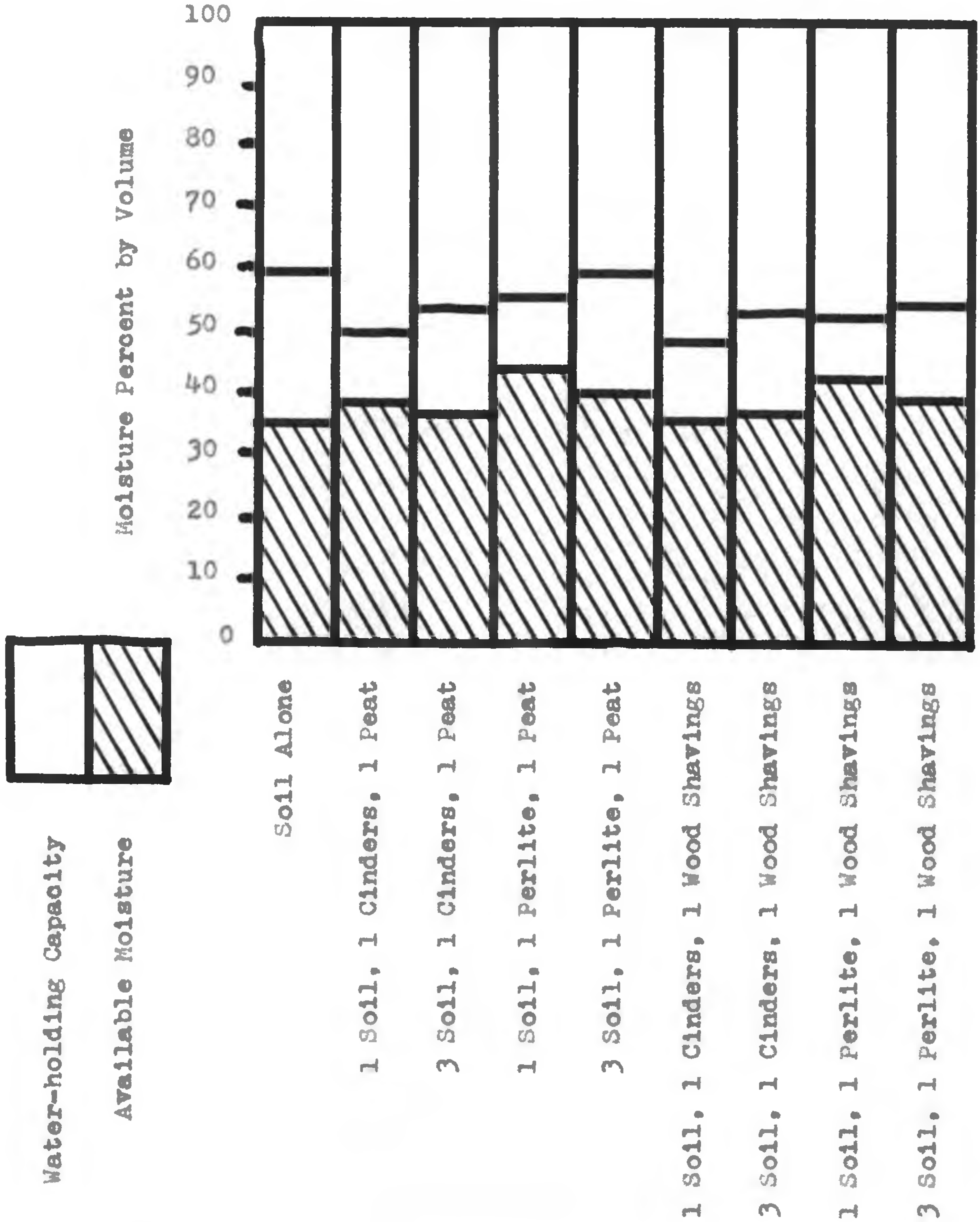

Figure 4. Water-holding capacity and available moisture in percent by volume of saturated soil in which panax plants were grown at the high fertility level

with the low percentage of soil, peat, and perlite. In mixes in which panax was grown significantly more available water was found in mixes containing perlite rather than cinders.

The differences in bulk density of the different mixes were mostly dependent on the bulk densities and percentages of their components. Soil alone always had a higher bulk density than amended soils. In media in which hibiscus plants were grown there was an interaction between percentage soil and inorganic amendments. Because of the large difference in the bulk densities of cinders and perlite, and the similar bulk densities of cinders and soil an apparent interaction is shown. In media in which hibiscus plants were grown there was also an apparent interaction between organic and inorganic amendments. Since the amendments were measured by volume it is likely that this interaction is due to the fact that the weight of the cinders compacted the peat while perlite did not. Wood shavings were probably not as susceptible to this packing action of the cinders. The same situation exists in the soil mixes in which panax plants were grown. The bulk densities of the mixes containing peat were higher than those with wood shavings.

Though bulk density itself probably has little to do with plant growth it is a very important factor in the trade. Wood shavings seem to have an advantage over peat in producing mixes of low bulk density. Cinders are considerably heavier than perlite and so if excessive weight is a determining factor in either handling the containers in the growing, processing, and sales areas, or transportation costs, it might be wise to consider some other amendment. Lower percentages of soil also figure prominently in the production of a lightweight soil mix. Too light a mix may not support the plant properly.

All the above data was taken from the high fertility portion of the experiment. Although there might be differences in these plant and soil properties between the high and low fertility treatments, probably the more important aspects are those concerned with those plants produced at an adequate level of fertilization. Table XXII shows that with the exception of (H+W)/2 (cm) of panax and hibiscus at 2.5 months, all grade and growth figures, for both species at both dates of observation, were significantly higher at the higher fertilization level. Combining the fertilizer treatments an effect on grade and growth of both species, except growth of panax, by soil treatment was shown. Table XXIII shows this effect though it is difficult to draw specific conclusions without further statistical analysis.

Table XXIV shows the interaction of fertilization level and soil treatments on visual grade of panax at 5.0 months. All plants produced at the higher fertilization level were of nearly the same grade and of higher grade than those produced at the lower fertilization level, except the mix of 3 parts soil, 1 part cinders, and 1 part peat, which was

TABLE XXII. EFFECT OF FERTILIZATION LEVEL ON GRADE AND

(H+W)/2 (cm) OF HIBISCUS AND PANAX

Months	Plant Material	Index	Low Fertility	High Fertility
2.5	Hibiscus	Grade	2.3	3.2**
"	"	Growth	47.9	54.2 N.S.
"	Panax	Grade	3.0	3.3**
"	"	Growth	25.6	27.5 N.S.
5.0	Hibiscus	Grade	2.4	3.2**
"	"	Growth	68.5	79.1**
"	Panax	Grade	2.3	2.8**
"	"	Growth	39.5	45.4**

N.S. Non-significant
** Significant at the 1% level

TABLE XXIII. EFFECT OF SOIL COMPOSITION ON VISUAL GRADE AND (H+W)/2 OF HIBISCUS AND PANAX COMBINING BOTH FERTILIZATION LEVELS AT 5.0 MONTHS

	Hibiscus		Panax	
Soil Mix	Grade	(H+W)/2	Grade	(H+W)/2
1 Soil	2.25	67.93	2.12	37.69
1 Soil 1 Cinders 1 Peat	3.12	79.19	2.75	45.81
3 Soil 1 Cinders 1 Peat	2.62	78.31	2.25	41.50
1 Soil 1 Perlite 1 Peat	2.62	70.31	3.00	45.44
3 Soil 1 Perlite 1 Peat	3.12	75.25	2.75	39.06
1 Soil 1 Cinders 1 Wood Shavings	2.62	75.12	2.62	45.25
3 Soil 1 Cinders 1 Wood Shavings	3.12	66.00	2.38	36.62
1 Soil 1 Perlite 1 Wood Shavings	3.00	76.31	2.50	43.56
3 Soil 1 Perlite 1 Wood Shavings	3.00	76.06	2.88	47.06
Significant at the	5% level,	5% level,	5% level,	N.S.

TABLE XXIV. INTERACTION OF SOIL COMPOSITION AND FERTILIZATION ON VISUAL GRADE OF PANAX AT 5.0 MONTHS

Soil Mix	Low Fertility	High Fertility
1 Soil	1.75	2.50
1 Soil, 1 Cinders, 1 Peat	2.50	3.00
3 Soil, 1 Cinders, 1 Peat	2.50	2.00
1 Soil, 1 Perlite, 1 Peat	2.75	3.25
3 Soil, 1 Perlite, 1 Peat	2.50	3.00
1 Soil, 1 Cinders, 1 Wood Shavings	2.25	3.00
3 Soil, 1 Cinders, 1 Wood Shavings	2.25	2.50
1 Soil, 1 Perlite, 1 Wood Shavings	1.75	3.25
3 Soil, 1 Perlite, 1 Wood Shavings	2.75	3.00

Linear soil mix X linear fertilization level 5%

considerably lower in grade and actually better grade plants were produced at the lower fertilization level.

Since grade and growth were greater at the higher level of fertilization it was taken as probably more closely approximating a good fertilization program. No statistical analysis has been made for data collected from treatments receiving the lower fertilization rate with the exceptions of grade and growth. No analysis has been performed on differences in response between the two species. No data is available for physical properties of the media except at the termination of the experiment. In spite of this lack of information certain relationships between time fertility and species may be found.

At 2.5 months panax seems to be a more sensitive plant for soil treatment although it was less sensitive to fertilization levels at this time. Panax grades fell off between 2.5 and 5.0 months. This could indicate that the plants had outgrown their containers and were reacting to this condition, or it may have been due to the season of the year, winter. Panax at 2.5 and 5.0 months seems to be more sensitive to percentage soil and to a lesser extent inorganic amendments. More significant differences in grade and growth of both species were found at 5.0 months. This may indicate that media have little affect on grade or growth during short growing periods.

It seems that water-holding capacity, available water and bulk density were higher in media in which panax plants were grown. This effect is probably due to the greater total amount of media left in the cans in which panax plants were grown. The root system of panax seemed to hold a higher percentage of the media in the cans than did the hibiscus. Available water in panax may also have been higher due to the ability of this plant to extract more water from the soil media. Bulk density may also have been affected by the differential erosive effects of the irrigation practices on the different media. More medium seemed to be lost from straight soil and to a lesser extent from media having the higher percentage of soil. Perhaps amendments have a stabilizing effect on media.

SUMMARY

Only significant differences in grade and growth of panax were detected at 2.5 months. This may indicate that panax was a more sensitive indicator plant. Soil treatments would also seem to be less important at this time. At 5.0 months a number of significant differences were apparent, indicating that perhaps soil treatment becomes more important as time goes on.

No judgments as to the desirability of any mix can be made, though it can be seen that when there were statistical differences, the lower percentage of soil was always better than the higher percentage, and amended soil was always better than soil alone. The economic considerations of media manufacture would probably outweigh these inconsistant differences in grade and growth.

Many differences in the physical properties of the mixes were found. No physical property or properties of any mix or mixes seemed to be limiting plant growth, although statistical verification has not been accomplished. How the various components and their relative percentages affect the physical properties is important to consider in relation to many problems concerning soil mixes.

Infiltration rate seems to be increased by amendments, but the interaction of the organic and inorganic amendments indicates that certain combinations of amendments have amplifying or diminishing affects on each other.

The water-holding capacity of soil alone was greater than that of amended soils, and the water-holding capacity of media with the higher percentage of soil was greater than the water-holding capacity of media with the lower percentage of soil. Soil then seems to be the main factor contributing to high water-holding capacity. This relationship of water-holding capacity and soil does not hold between soil and available moisture.

Many mixes with high water-holding capacity actually had less available water. Amended soils had more available water than soil alone. Of the mixes in which hibiscus was grown the highest available water was found in the mix containing the low percentage of soil, peat and perlite. In the mixes in which panax plants were grown significantly more available water was found in mixes containing perlite rather than cinders.

The bulk densities of the mixes were mostly dependent on the bulk densities of the mix components and their relative percentages. High percentages of soil and or cinders resulted in high bulk densities. Heavy components in the mix tend to compact peat, but not wood shavings, causing peat to affect bulk density according to the weight of the other components in the mix.

Greater growth and grade were found in almost all instances at the high fertility level.

Appendix A. Analysis of variance of visual grade of hibiscus at 2.5 months and high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	0.99	3.81*	3.01	4.72
Treatments	8	0.19	0.70	2.36	3.36
Soil vs. Amended Soil	1	0.28	1.08	4.26	7.82
Percentage Soil	1	0.78	3.00	"	"
Inorganic Amendments	1	0.03	0.12	"	"
Organic Amendments	1	0.03	0.12	"	"
P.S. X I.A.	1	0.28	1.08	"	"
P.S. X O.A.	1	0.03	0.12	"	"
I.A. X O.A.	1	0.03	0.12	"	"
P.S. X I.A. X O.A.	1	0.03	0.12	"	"
Error	24	0.26			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix B. Analysis of variance of visual grade of panax at 2.5 months and high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	2.07	5.75**	3.01	4.72
Treatments	8	0.85	2.36*	2.36	3.36
Soil vs. Amended Soil	1	0.03	0.08	4.26	7.82
Percentage Soil	1	2.53	7.03*	"	"
Inorganic Amendments	1	0.03	0.08	"	"
Organic Amendments	1	0.28	0.77	"	"
P.S. X I.A.	1	2.53	7.03*	"	"
P.S. X O.A.	1	0.03	0.08	"	"
I.A. X O.A.	1	0.03	0.08	"	"
P.S. X I.A. X O.A.	1	1.53	4.25	"	"
Error	24	0.36			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix C. Analysis of variance of (H+W)/2 of hibiscus at 2.5 months and high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	9.75	0.19	3.01	4.72
Treatments	8	60.14	1.19	2.36	3.36
Soil vs. Amended Soil	1	44.73	0.89	4.26	7.82
Percentage Soil	1	4.88	0.10	"	"
Inorganic Amendments	1	27.19	0.54	"	"
Organic Amendments	1	130.00	2.58	"	"
P.S. X I.A.	1	14.44	0.29	"	"
P.S. X O.A.	1	76.57	1.52	"	"
I.A. X O.A.	1	164.25	3.26	"	"
P.S. X I.A. X O.A.	1	18.75	0.37	"	"
Error	24	50.45			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix D. Analysis of variance of (H+W)/2 of panax at 2.5 months and high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	46.21	2.32	3.01	4.72
Treatments	8	38.84	1.95	2.36	3.36
Soil vs. Amended Soil	1	17.75	0.89	4.26	7.82
Percentage Soil	1	114.38	5.76*	"	"
Inorganic Amendments	1	61.88	3.11	"	"
Organic Amendments	1	0.07	0.00	"	"
P.S. X I.A.	1	15.82	0.80	"	"
P.S. X O.A.	1	0.63	0.03	"	"
I.A. X O.A.	1	17.25	0.87	"	"
P.S. X I.A. X O.A.	1	82.88	4.17	"	"
Error	24	19.87			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix E. Analysis of variance of visual grade of hibiscus at 5.0 months and high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	0.67	2.31	3.01	4.72
Treatments	8	0.65	2.24	2.36	3.36
Soil vs. Amended Soil	1	2.35	8.10**	4.26	7.82
Percentage Soil	1	0.50	1.72	"	"
Inorganic Amendments	1	0.00	0.00	"	"
Organic Amendments	1	0.12	0.41	"	"
P.S. X I.A.	1	1.13	3.90	"	"
P.S. X O.A.	1	0.00	0.00	"	"
I.A. X O.A.	1	0.00	0.00	"	"
P.S. X I.A. X O.A.	1	1.12	3.86	"	"
Error	24	0.29			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix F. Analysis of variance of visual grade of panax at 5.0 months and high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	1.89	7.88**	3.01	4.72
Treatments	8	0.69	2.88*	2.36	3.36
Soil vs. Amended Soil	1	0.50	2.08	4.26	7.82
Percentage Soil	1	2.00	8.33**	"	"
Inorganic Amendments	1	2.00	8.33**	"	"
Organic Amendments	1	0.12	0.50	"	"
P.S. X I.A.	1	0.50	2.08	"	"
P.S. X O.A.	1	0.12	0.50	"	"
I.A. X O.A.	1	0.12	0.50	"	"
P.S. X I.A. X O.A.	1	0.12	0.50	"	"
Error	24	0.24			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix G. Analysis of variance of (H+W)/2 of hibiscus at 5.0 months and high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	95.14	1.40	3.01	4.72
Treatments	8	124.08	1.82	2.36	3.36
Soil vs. Amended Soil	1	18.00	0.26	4.26	7.82
Percentage Soil	1	0.31	0.00	"	"
Inorganic Amendments	1	21.12	0.31	"	"
Organic Amendments	1	132.03	1.94	"	"
P.S. X I.A.	1	132.03	1.94	"	"
P.S. X O.A.	1	338.00	4.96*	"	"
I.A. X O.A.	1	306.28	4.50*	"	"
P.S. X I.A. X O.A.	1	45.12	0.66	"	"
Error	24	68.03			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix H. Analysis of variance of (H+W)/2 of panax at 5.0 months and high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	176.36	4.61*	3.01	4.72
Treatments	8	95.03	2.48*	2.36	3.36
Soil vs. Amended Soil	1	40.50	1.06	4.26	7.82
Percentage Soil	1	399.03	10.43**	"	"
Inorganic Amendments	1	1.53	0.04	"	"
Organic Amendments	1	2.53	0.07	"	"
P.S. X I.A.	1	200.00	5.22*	"	"
P.S. X O.A.	1	72.00	1.88	"	"
I.A. X O.A.	1	28.12	0.73	"	"
P.S. X I.A. X O.A.	1	16.53	0.43	"	"
Error	24	38.26			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix I. Analysis of variance of infiltration rate of media in which hibiscus plants were grown at high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	2399329.97	5.65**	3.01	4.72
Treatments	8	1182376.05	2.78*	2.36	3.36
Soil vs. Amended Soil	1	3064256.42	7.21*	4.26	7.82
Percentage Soil	1	1523821.53	3.59	"	"
Inorganic Amendments	1	14407.53	0.03	"	"
Organic Amendments	1	3870457.53	9.11**	"	"
P.S. X I.A.	1	1.53	0.00	"	"
P.S. X O.A.	1	2538.28	0.01	"	"
I.A. X O.A.	1	980350.03	2.31	"	"
P.S. X I.A. X O.A.	1	3180.03	0.01	"	"
Error	24	424914.64			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix J. Analysis of variance of infiltration rate of media in which panax plants were grown at high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	135206.59	1.53	3.01	4.72
Treatments	8	163382.27	1.85	2.36	3.36
Soil vs. Amended Soil	1	212443.35	2.41	4.26	7.82
Percentage Soil	1	330891.12	3.75	"	"
Inorganic Amendments	1	61776.12	0.70	"	"
Organic Amendments	1	32640.12	0.37	"	"
P.S. X I.A.	1	29161.12	0.32	"	"
P.S. X O.A.	1	10878.12	0.12	"	"
I.A. X O.A.	1	618828.12	7.02*	"	"
P.S. X I.A. X P.A.	1	10440.12	0.12	"	"
Error	24	88123.25			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix K. Analysis of variance of total water of media in which hibiscus plants were grown at high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	1976.10	0.47	3.01	4.72
Treatments	8	52237.82	12.87**	2.36	3.36
Soil vs. Amended Soil	1	72421.84	17.84**	4.26	7.82
Percentage Soil	1	184680.03	45.49**	"	"
Inorganic Amendments	1	8613.28	1.900	"	"
Organic Amendments	1	105225.78	25.92**	"	"
P.S. X I.A.	1	15356.28	3.40	"	"
P.S. X O.A.	1	385.03	0.08	"	"
I.A. X O.A.	1	20452.53	4.53*	"	"
P.S. X I.A. X O.A.	1	10767.78	2.39	"	"
Error	24	4509.97			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix L. Analysis of variance of total water of media in which panax plants were grown at high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	7788.99	1.35	3.01	4.72
Treatments	8	25320.69	4.40**	2.36	3.36
Soil vs. Amended Soil	1	51654.34	8.99**	4.26	7.82
Percentage Soil	1	38157.03	6.64*	"	"
Inorganic Amendments	1	71158.78	12.39**	"	"
Organic Amendments	1	21788.28	3.79	"	"
P.S. X I.A.	1	3894.03	0.68	"	"
P.S. X O.A.	1	75.03	0.01	"	"
I.A. X O.A.	1	15007.78	2.61	"	"
P.S. X I.A. X O.A.	1	830.28	0.14	"	"
Error	24	5744.66			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix M. Analysis of variance of available water of media in which hibiscus plants were grown at high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	2660.52	1.01	3.01	4.72
Treatments	8	31264.92	11.89**	2.36	3.36
Soil vs. Amended Soil	1	45727.92	17.39**	4.26	7.82
Percentage Soil	1	12051.28	4.58*	"	"
Inorganic Amendments	1	90206.28	34.31**	"	"
Organic Amendments	1	65250.78	24.81**	"	"
P.S. X I.A.	1	17066.28	6.49*	"	"
P.S. X O.A.	1	2983.78	1.13	"	"
I.A. X O.A.	1	1212.78	0.46	"	"
P.S. X I.A. X O.A.	1	15620.28	5.94*	"	"
Error	24	2629.50			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix N. Analysis of variance of available water of media in which panax plants were grown at high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	12193.65	2.99	3.01	4.72
Treatments	8	16223.56	3.98**	2.36	3.36
Soil vs. Amended Soil	1	29768.00	7.31*	4.26	7.82
Percentage Soil	1	12720.12	3.12	"	"
Inorganic Amendments	1	71631.12	17.58**	"	"
Organic Amendments	1	7626.12	1.87	"	"
P.S. X I.A.	1	3960.50	0.97	"	"
P.S. X O.A.	1	1800.00	0.44	"	"
I.A. X O.A.	1	4.50	0.00	"	"
P.S. X I.A. X O.A.	1	2278.12	0.56	"	"
Error	24	4074.72			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix O. Analysis of variance of bulk density of media in which hibiscus plants were grown at high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	.00019	0.30	3.01	4.72
Treatments	8	.05466	86.76**	2.36	3.36
Soil vs. Amended Soil	1	.04310	68.41**	4.26	7.82
Percentage Soil	1	.07421	117.79**	"	"
Inorganic Amendments	1	.26445	419.76**	"	"
Organic Amendments	1	.00435	6.90*	"	"
P.S. X I.A.	1	.02826	44.81**	"	"
P.S. X O.A.	1	.00020	0.31	"	"
I.A. X O.A.	1	.02127	33.76**	"	"
P.S. X I.A. X O.A.	1	.00144	2.28	"	"
Error	24	.00063			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix P. Analysis of variance of bulk density of media in which panax plants were grown at high fertility

Source	df	ms	F	F Required .05	.01
Replications	3	.00028	0.30	3.01	4.72
Treatments	8	.04609	48.52**	2.36	3.36
Soil vs. Amended Soil	1	.09181	96.64**	4.26	7.82
Percentage Soil	1	.06337	66.71**	"	"
Inorganic Amendments	1	.19782	208.23**	"	"
Organic Amendments	1	.00775	8.16**	"	"
P.S. X I.A.	1	.00437	4.60*	"	"
P.S. X O.A.	1	.00013	0.13	"	"
I.A. X O.A.	1	.00162	1.70	"	"
P.S. X I.A. X O.A.	1	.00189	1.98	"	"
Error	24	.00095			
Total	35				

*Significant at the 5% level
**Significant at the 1% level

Appendix Q. Analysis of variance of visual grade of hibiscus at 2.5 months

Source	df	ms	F	F Required .05	.01
Replications	3	0.94	4.09*	2.79	4.20
Fertilization	1	17.01	73.96**	4.03	7.17
Soil Treatments	8	0.22	0.96	2.13	2.88
F X S.T.	8	0.43	1.87	"	"
Error	51	0.23			
Total	71				

*Significant at the 5% level
**Significant at the 1% level

Appendix R. Analysis of variance of visual grade of panax at 2.5 months

Source	df	ms	F	F Required .05	.01
Replications	3	0.75	1.63	2.79	4.20
Fertilization	1	2.35	5.11*	4.03	7.17
Soil Treatments	8	0.74	1.61	2.13	2.88
F X S.T.	8	0.66	1.43	"	"
Error	51	0.46			
Total	71				

*Significant at the 5% level
**Significant at the 1% level

Appendix S. Analysis of variance of (H+W)/2 of hibiscus at 2.5 months

Source	df	ms	F	F Required .05	.01
Replications	3	24.02	0.14	2.79	4.20
Fertilization	1	696.89	4.00	4.03	7.17
Soil Treatments	8	55.74	0.32	2.13	2.88
F X S.T.	8	31.95	0.18	"	"
Error	51	174.39			
Total	71				

*Significant at the 5% level
**Significant at the 1% level

Appendix T. Analysis of variance of (H+W)/2 of panax at 2.5 months

Source	df	ms	F	F Required .05	.01
Replications	3	13.64	0.41	2.79	4.20
Fertilization	1	65.17	1.94	4.03	7.17
Soil Treatments	8	53.44	1.60	2.13	2.88
F X S.T.	8	7.94	0.24	"	"
Error	51	33.49			
Total	71				

*Significant at the 5% level
**Significant at the 1% level

Appendix U. Analysis of variance of visual grade of hibiscus at 5.0 months

Source	df	ms	F	F Required .05	.01
Replications	3	1.59	4.97**	2.79	4.20
Fertilization	1	10.89	34.03**	4.03	7.17
Soil Treatments	8	0.78	2.44*	2.13	2.88
F X S.T.	8	0.23	0.72	"	"
Error	51	0.32			
Total	71				

*Significant at the 5% level
**Significant at the 1% level

Appendix V. Analysis of variance of visual grade of panax at 5.0 months

Source	df	ms	F	F Required .05	.01
Replications	3	1.87	7.19**	2.79	4.20
Fertilization	1	4.50	17.31**	4.03	7.17
Soil Treatments	8	0.69	2.65*	2.13	2.88
F X S.T.	8	0.56	2.15*	"	"
Error	51	0.26			
Total	71				

*Significant at the 5% level
**Significant at the 1% level

Appendix W. Analysis of variance of (H+W)/2 of hibiscus at 5.0 months

Source	df	ms	F	F Required .05	.01
Replications	3	3597.79	60.06**	2.79	4.20
Fertilization	1	2016.12	33.66**	4.03	7.17
Soil Treatments	8	172.04	2.87*	2.13	2.88
F X S.T.	8	56.27	0.94	"	"
Error	51	59.90			
Total	71				

*Significant at the 5% level
**Significant at the 1% level

Appendix X. Analysis of variance of (H+W)/2 of panax at 5.0 months

Source	df	ms	F	F Required .05	.01
Replications	3	74.69	1.32	2.79	4.20
Fertilization	1	618.35	10.94**	4.03	7.17
Soil Treatments	8	119.57	2.12	2.13	2.88
F X S.T.	8	53.79	0.95	"	"
Error	51	56.53			
Total	71				

*Significant at the 5% level
**Significant at the 1% level

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